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REVIEWS.

RECENT CONTRIBUTIONS TO THE SUBJECT OF DYNAMOMETAMORPHISM FROM THE ALPS.

A. Heim: Geologie der Hochalpen zwischen Reuss und Rhein. Beiträge zur geologischen Karte der Schweiz, Vol. XXV., 4°: Bern, 1891, pp. 503.

C. Schmidt: Beiträge zur Kenntniss der auftretenden Gesteine. ib. Anhang, pp. 76.

L. Milch: Beiträge zur Kenntniss des Verrucano. Erster Theil : Leipzig, 1892, pp. 145.

M. P. Termier: Etude sur la Constitution géologique du Massif de la Vanoise. Bull. des Services de la Carte géol. de France. No. 20, Paris, 1891, pp. 147.

For many years both Huttonian (metamorphic) and Wernerian (original deposition) principles have been advanced to explain the crystalline schists of the Alps, as well as those of other regions. Because of their youth these great mountains are in many ways peculiarly fitted to throw light upon the difficult problems presented by these rocks. Many of the most classic Alpine localities are now being investigated by modern methods and are yielding welcome results which tend to establish not merely the fact, but also the nature, cause and processes of metamorphism.

Nowhere is this more true than in the region of vast earth-movements which Professor Heim of Zurich, has made the scene of his life work. As the result of his labors in this field, he was able to publish in 1878 his monograph on the Tödi-Windgälle group and the accompanying essay on the Mechanism of Mountain-making—a work which must certainly be regarded as epoch-making in suggesting the clue to a satisfactory explanation of the problems of regional metamorphism. This book Professor Heim now supplements with another of almost equal size, which contains the explanatory and descriptive text of the remainder of Sheet XIV of the Geological Survey of Switzerland. This map, which was published on a scale of 1 : 100,000 in 1885, embraces the area between the St. Gotthard railway and the Rhein, north of the great central (Tessin) massif which forms the south flank of the Alps. Hence it includes the eastern portion of the Aar and Gotthard massifs, with all the younger formations in their most disturbed and implicated development. The thirteen years which have elapsed since the appearance of the earlier work have so greatly multiplied observations and stimulated thought that the standpoint regarding the whole subject of dynamic metamorphism is seen to be far advanced. Nor has Professor Heim himself been instrumental in any small way in bringing about this result. Aside from his own detailed field work, his suggestions as to the efficacy of orographic movement as a metamorphosing agent have been of profound and world-wide influence. Hence we cannot be surprised that he should have inspired enthusiastic students within the limits of his own special field. Others have worked out under his direction many details upon which some of his own broadest and most far-reaching generalizations rest. Some of the best of these results appear almost simultaneously with his latest work and form an integral portion of it. This is notably true of the special petrographic studies of both the eruptive and sedimentary rocks of two important and much discussed horizons—the Bündnerschiefer and the Verrucano—in both of which the processes of dynamometamorphism can be made out clearly and precisely followed.

More than one quarter of the Swiss atlas sheet XIV is occupied by that diversified complex of phyllites and schists, called by Heim the *Bündnerschiefer*. Their stratigraphical relations are, on account of the dislocations to which they have been subjected, often very obscure. They have been variously interpreted by different observers, but as the result of years of mature observation Professor Heim gives a full presentation of the facts, and now concludes that he must differ with Bonney, Gümbel, Diener and others who have ascribed to them a greater age, and agree with A. Escher v. d. Linth, Theobold and Rolle who regard them as a united and continuous series belonging in the main to the Lias. Toward the east, where these schists have their broadest and least disturbed development, they are comparatively little altered, and consist of calcareous shales and phyllites, impure limestones, sandstones, dolomitic and gypseous beds, interstratified with green schists and serpentine which are shown by microscopical examination to be altered volcanic material in conformable layers. Farther west, where these same rocks become tightly compressed between the gneisses of the central massifs, they have become recrystallized in proportion to the amount of their dislocation. "The study of the Bündnerschiefer," says Heim, "was that which years ago first convinced me of the possibility and reality of crystalline metamorphism being produced without the agency of eruptive contact, since I here for the first time observed how a belemnitiferous calcareous argillite became gradually more and more crystalline by the development of such minerals as mica, garnet, hornblende, zoisite, etc., at first as indistinct and imperfect nodules, and later as good crystals" (l. c., p. 52). The Bündnerschiefer, both in their less altered localities and in occasional beds, which have been by chance saved from metamorphism, are quite rich in Jurassic fossils.

About one-half of Professor C. Schmidt's appendix to Professor Heim's monograph is devoted to the petrographical description of the Bündnerschiefer, while the remainder treats of the crystalline rocks of the Aar, Gotthard and Adula massifs. A few preliminary remarks on the melaphyre of the Kärpfstock supplement the author's earlier communications with reference to the eruptives occurring in the Glarner double-fold.[1] The rocks from the three crystalline massifs are mainly the characteristic Alpine gneiss-granites or protogine, with dioritic or amphibolitic interpositions. Sericite- ottrelite- paragonite- zoisite- glaucophane-schists and eclogites also occur. The Adula gneiss is characterized by a green potash-mica (phengite) which is both uniaxial and biaxial. The rocks of the *Bündnerschiefer* are described by Schmidt under two principal heads: *a*) gray and black schists which are more or less completely metamorphosed sediments; and *b*), green schists which are foliated and metamorphosed eruptive material. Under the first division are mentioned schists with newly crystallized chloritoid, zoisite, tourmaline, epidote, biotite, muscovite, quartz, plagioclase and rutile. In some cases complete pseudomorphs of zoisite after echinoid remains are to be found. Other more tightly compressed beds at Nufenen, Val Piora, Lukmanier, Scopi, Ariolo, and other localities are still more highly crystalline, containing disthene, garnet, staurolite and similar minerals in abundance. These rocks have also been petrographically studied by Prof. U. Grubenmann.[2]

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[1] Neues Jahrbuch für Min., etc., Beil. Bd. IV., p. 288, 1886. Ib., 1887, I., p. 58.

[2] Mitth. Thurgauischen Naturf. Gesellsch., Heft. VIII., 1888.

The second division or green schists include foliated gabbro, diabase, variolite, serpentine and various pyroclastic deposits now filled with new epidote, uralite, chlorite, saussurite and other secondary products. They show many points of analogy with the greenstone schist areas of the Marquette and Menominee districts on Lake Superior. Of more than usual interest are Schmidt's descriptions of the chloritic ferruginous oölite of Callovien. This was once a glauconitic oölite of Jurassic age, whose spherical particles have, by dynamometamorphism, been flattened, while their iron has crystallized as magnetite and hematite, and their glauconite changed to chlorite. The process of metamorphism in the Bündnerschists is summed up by Schmidt as follows: "The first stage of the metamorphism of the sediments always consists in the development of rutile microliths, as well as isolated and usually skeleton crystals whose nature depends on the composition of the metamorphosed material. These new phenocrysts gradually increase both in number and size; they are always filled with abundant inclusions of the groundmass whose sedimentary arrangement is not destroyed within the newly formed phenocryst. Finally, the clastic groundmass is transformed into an aggregate of crystalline minerals; and, where the metamorphism is most intense, the contrast between new phenocrysts and groundmass is least distinct." (l. c., p. 71.)

As a result of both his own and Schmidt's work, Heim concludes (l. c. p. 488): 1) that all the demonstrable orographic disturbance, and hence all the dynamometamorphism within his area, is post-Eocene, and much of it post-Miocene; 2) that two sorts of metamorphism must be distinguished. The recent dynamic metamorphism which was caused by, and hence was synchronous with orographic movement; and the much more ancient and probably still continuous metamorphism due to heat, moisture, and simple pressure without motion, which he calls *diagenetic* metamorphism (statical metamorphism of Judd). He contrasts the effects of mechanical metamorphism upon highly crystalline and sedimentary rocks, in that the same cause crushes the former into a finely granular schistose series, and recrystallizes the latter by developing large phenocrysts within them. He attributes these results in his particular Alpine region entirely to dynamic action, since he can find no trace of eruptive material which could have produced contact metamorphism in rocks of tertiary age.

The regret expressed by Professor Heim at the time of writing his text that no one had been found to thoroughly investigate the dynamic phenomena of the Verrucano seems about to be removed by the work now being published by Dr. L. Milch of Breslau. He has recently offered as his *habilitationschrift* the first part of his petrographical study of the Verrucano rocks of Graubünden, which deals with the historical development of the knowledge of this formation and the dynamic metamorphism of the eruptive rocks occurring in it. The second part, to be published later, will treat of the metamorphosed sediments and chemical aspects of the whole subject. The basic carboniferous eruptives of the region investigated are all melaphyres belonging to the three types: olivine-weisselbergite, navite and tholeiite; in other words old basalts. Some of them are well preserved, and show clearly the progressive effects of metamorphism with increasing mechanical disturbance. Some of the rocks are massive and others amygdaloidal, but the effect of the pressure is finally to destroy all of their original characters and to produce from them chloritic, epidotic, sericitic, or carbonate schists, which could just as well have originated from sediments of the proper composition. The mechanical action differentiates the originally homogeneous rock into portions of very different mineralogical composition, which in the most squeezed parts of a fold form fine parallel layers, but in the less compressed areas are intimately interlaced. Thus the same orographic force, while it may produce the same result from rocks genetically very distinct, can also, on the other hand, produce highly diverse rocks from one and the same mass.

The acid Carboniferous eruptives of the area studied are quartz-porphyries, or old rhyolites. Some of these form an important part of the pebbles in the Verrucano conglomerates, while others occur *in situ* as a contemporaneous part of this formation. The latter rocks show many points of resemblance with the Windgälle porphyries, considered by Heim and Schmidt (N. J. B. BB. IV., 1886) as pre-Carboniferous. Milch distinguishes two categories of metamorphic changes exhibited by these acid eruptives. The first is mainly *mechanical,* consisting of crushing and granulation, and producing fine-grained, jaspery schists; the second is mainly *chemical,* producing sericite from the feldspathic constituents which forms interlacing membranes. There is then here observable a complementary relation between the mechanical and chemical work of dynamometamorphism, like that pointed out by the present writer in the greenstone-schists and associated rocks of Lake Superior. (Bull. U. S. Geol. Surv., No. 62).

Professor Termier of the Ecole des Mines at Saint-Etienne has given in his essay on the constitution of the Vanois massif in Savoy, another excellent contribution to our knowledge of the effects of orographic movement in metamorphosing Alpine sediments of Caboniferous and Triassic age. This is all the more welcome from France where dynamometamorphism has been rather slow to gain recognition, in spite even of the convicting demonstrations by Gosselet in the Ardennes. The *schistes lustrés*, which bound the Vanois massiv on the east, considered by Lory as upper Triassic, are made by Termier pre-Carboniferous. The principal horizons which have been studied with reference to metamorphism are the Permian and Trias. The former is represented mainly by quartzites and phyllites, altered and recrystallized in proportion to the disturbance they have suffered. In the phyllites rutile, sphene, tourmaline, garnet, zoisite, epidote, glaucophane, chloritoid, various micas and feldspars, and quartz have been abundantly developed. Many interesting details and figures are given to illustrate the development of these new minerals. Albite crystals by their growth in the phyllite have sometimes displaced all, or only a part of the original schist constituents, while in other cases they have not disturbed their position at all. Various minerals are traced in their gradual development from indistinct nodules to perfect crystals. Only the metamorphism of sedimentary beds is considered, and the general conclusion is reached that their alteration is independent of eruptive action, and entirely conditioned by the heat produced by orographic movements. This heat is supposed to have been very gradually produced and very slowly dissipated. The author thinks that a temperature of 200 to 250 C., continued through ages, would suffice to crystallize new compounds like feldspar, quartz, carbonates, tourmaline, chlorite, micas, ilmenite, rutile, etc., without affecting the bulk composition of the rock. In exceptional cases an intenser movement might give a temperature of 300 C., sufficient to produce amphibole, which will appear as glaucophane, if, as in his Permian beds, the original sediments are very rich in soda.

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